A NUPTIAL SECONDARY SEX-CHARACTER IN FUNDULUS HETEROCLITUS

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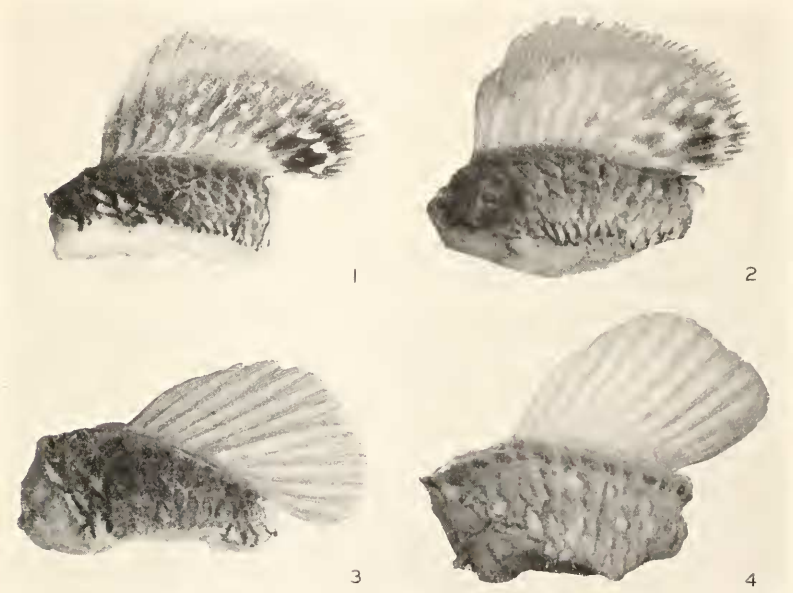
Everyone who has selected *Fundulus* for eggs or sperm is familiar with the striking coloration pattern in the males and especially with the dark splotch in the posterior part of the dorsal fin in this sex (Newman, 1907). This splotch is made up of melanophores and is not without interest. To test its constancy in relation to sex one hundred killifishes were opened during the breeding season (June, 1934) and their sex determined by an inspection of their gonads. Forty-seven of these fishes proved to be males and fifty-three females. All the males exhibited the fin-mark already alluded to and none of the females showed it. Apparently it is a character accurately associated with sex.

It is in all essential respects undisturbed by the change of *Fundulus* from the dark to the light condition or the reverse. Figure 1 shows the dorsal fin of a male fish in the dark phase, and notwithstanding the generally deep tone of the fin, the nuptial mark stands out conspicuously. The anterior three-fourths of the free edge of the fin contains so few melanophores as to appear quite light. The rest of the fin carries the nuptial mark composed of a great abundance of large melanophores. Here and there in this part of the fin are elongated light-spots parallel with the rays. The last few interrays near the posterior edge of the fin are, on the whole, densely black with several striking light-spots that add intensity to the mark. This darkened area and especially its posterior portion is what we have called the nuptial mark. In the light condition of the males the mark, especially its posterior part, is still conspicuous (Fig. 2). In the female the dorsal fin is uniformly dotted over with melanophores which neither in the dark state (Fig. 3) nor in the light one (Fig. 4) show any special concentration.

About a quarter of an hour after a male *Fundulus* has been put into a white-walled illuminated vessel it will have become extremely light-tinted in that the pigment in its skin melanophores will have assumed a high degree of concentration. The nuptial mark, however, will remain under these circumstances conspicuously dark as though the pigment of its melanophores had failed to concentrate. If, however, this spot is examined under the microscope it will be seen to be made up of many melanophores, both large and small, in all of which the pigment is

strongly concentrated. Their number, however, is so great as compared with that in equal areas of other parts of the body that notwithstanding the state of their pigment they form a dark area. But the nuptial spot is not only a rich aggregation of melanophores; it is a region in which a large amount of free melanin occurs. This melanin is in the form of clumps in the tissue spaces of the skin and probably results from the disintegration of color-cells in which it was once contained. In this way the nuptial mark in a light fish remains a con-



Four enlarged views of the dorsal fins of *Fundulus heteroclitus,* two from males and two from females, one in each sex for the light condition and the other for the dark. In each instance the anterior edge of the fin is to the left. Photographs by Dr. F. M. Carpenter.

Fig. 1. Dorsal fin of a male in dark condition.
Fig. 2. Dorsal fin of a male in light condition.
Fig. 3. Dorsal fin of a female in dark condition.
Fig. 4. Dorsal fin of a female in light condition.

spicuous feature even though the pigment in its melanophores may have gone into a concentrated state.

Fundulus, some ten minutes after it has received a subcutaneous injection of adrenalin, will become extremely light in that the pigment in both its large and its small melanophores will have become maximally concentrated. But even in this extreme state the male nuptial mark is still conspicuous and for the same reason as that already given; its melanophores are so numerous that even though their pigment is con-

centrated by adrenalin, they nevertheless constitute a dark area in the fin of a light fish. Their response to adrenalin allies them with the melanophores of the rest of the fish, but puts them in contrast with the yellow and red cells in the so-called "Hochzeitskleid" of *Phoxinus*, which, according to Abolin (1925*a*) and to Giersberg (1930) are not influenced by adrenalin.

The male nuptial mark has an interesting history throughout the year. This history has been followed for some eighteen months on material in part from Woods Hole and in part from the neighborhood of Boston, Massachusetts. No nuptial marks have been noticed in male *Fundulus* from these localities between the months of November and of March. In April the mark begins to appear. It is present in May, is well pronounced in June and July, diminishes in August, and disappears in November. It is therefore quite clearly a mark of the breeding season, as in fact the generally high coloration of the male also is. It does not, however, belong to that group of color changes such as have been studied recently by Wunder (1931) in *Rhodeus* and which momentarily flash up in the male during the breeding act. It is a permanent sign of the whole breeding season and its limitation to one sex suggests that it may result from some male neurohumor produced during that period and acting on a specially receptive area in the dorsal fin of the fish. (See Abolin, 1925*b*.)

Summary

The male of *Fundulus heteroclitus* possesses a secondary sex-character in the form of a melanophoric mark on its dorsal fin to be seen from April to November but not at other times of the year. It may therefore be described as nuptial. It does not occur in the female. It is composed of an unusually dense aggregation of melanophores whose melanin even when concentrated (light phase) forms a conspicuous dark mark.

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